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Exploring the determinants of variations in land use policy outcomes:

What makes urban containment work?

Abstract: This article explores ways in which land use policy outcomes vary across contexts focusing, as an example, on urban growth boundaries. Specifically, it analyzes how various contextual factors interact with the policy and generate diverging development outcomes by employing a kernel-based regularized least squares method. Results show that the policy effectiveness is largely dependent on the region's population size, initial density levels, and organizational conditions. The presence of urban growth boundaries also appears to shape the way other determinants influence development patterns, suggesting that the policy can both directly and indirectly promote a more compact/contiguous pattern of development.

Introduction

While land use planners have long sought *good* policies (and have often tried to replicate what other cities/regions have done), it is no secret that land use policy outcomes vary significantly. Few policies, if any, have been found to work as expected in attaining their goals consistently across cities and over time. For a majority of land use policy instruments, the evaluation outcomes are quite equivocal, suggesting that a certain policy tends to be effective in some settings, but not in other circumstances.

For instance, studies on the effectiveness of urban growth boundaries (UGBs) – which have been adopted by a growing number of cities and regions in an attempt to curb sprawl and promote more compact/contiguous development – have reported mixed findings (see, e.g., Woo and Guldmann 2011; Kline et al., 2014; and Section *Previous Research – Mixed Findings*, for a more detailed discussion). Although the degree of variability differs from one area to another, there are similarly mixed conclusions in the literature concerning impact fees (Evans-Cowley and Lawhon, 2003), inclusionary zoning (Schuetz et al., 2009), and new urbanism (Cabrera and Najarian, 2013), to name a few.

The great extent of the variation in land use policy outcomes raises two important issues for both planning researchers and practitioners: (i) why such variation exists (i.e., what factors account for such variations); and (ii) under what circumstances a policy of interest is more likely to be effective. From a pragmatic point of view, it would be more beneficial to address these questions rather than to seek a panacea that can guarantee success in all or most settings. However, there has been surprisingly little effort to advance knowledge on this front. While many empirical studies have detected varying policy effects, little is known about what exactly caused the variation. Many articles close with a fairly general conclusion, such as *context matters*. It is not uncommon that answering *why* is left for future work.

A systematic investigation is needed to remove such vagueness and provide a more thorough understanding of the complex nature of land use policy outcomes. This study attempts to take a step in that direction by exploring the mechanisms behind varying land use policy outcomes. More specifically, the present study tries to identify key contextual factors that can account for the variation, focusing on UGBs, as an example. Using data for 85 single-county metropolitan areas in the US, an investigation is made to unravel how various factors (such as size, history/culture, geography, governance, and market conditions/forces) interacted with the policy and generated diverging UGB outcomes between 2001 and 2011. This is accomplished by employing an innovative kernel-based regression analysis technique that estimates the pointwise partial derivatives and captures (potentially) complex interactions between the variables. The results show ways in which the policy effectiveness can be influenced by other factors, providing an opportunity to better understand the context-specific workings of the policy.

Previous Research – Mixed Findings

Over the last several decades, UGBs have been implemented widely as a means to induce a more compact and/or contiguous form of urban development, assumed to be more desirable than unlimited expansion – often called sprawl – for various reasons (see, e.g., Easley, 1992; Knaap and Nelson, 1992; Nelson and Peterman, 2000; Ingram et al., 2009; Chapin, 2012). The logic of this policy instrument is fairly straightforward, typically starting with a projection of future demand for residential and commercial/industrial space and site suitability analysis. With careful consideration of these projection and analysis outcomes, a boundary surrounding core (predeveloped) areas is delineated in which new development should be directed. Once adopted after multiple rounds of review and approval, development for urban purposes is generally not permitted outside of the boundary, though exceptions exist. When needed, the boundary established at a certain time point can be expanded or adjusted to better guide development processes in the future.

As the implementation of such a policy has become more widespread, an increasing number of studies have been devoted to assessing whether it is really successful in attaining its primary goals (i.e., more compact and/or contiguous development) or if it generates unwanted side effects, such as rapid land or housing price escalation and associated affordable housing problems (see, e.g., Phillips and Goodstein, 2000; Carruthers, 2002; Downs, 2004; Landis, 2006). While a great deal of attention has been paid to some well-known cases of UGB implementation, particularly in Portland and other cities/regions in the state of Oregon, additional studies have focused on other areas in the US and beyond. Moreover, recent studies have evaluated the effectiveness of UGBs by comparing a number of cities/regions to similar cities/regions without the policy intervention using cross-sectional or panel analysis methods (see, e.g., Nelson et al., 2004; Woo and Guldmann, 2011).

Early evaluations were mainly conducted in the form of a conventional case study with the use of some indicators that could inform how physical development occurred under the influence of UGBs. Nelson and Moore (1993), for instance, assessed the effectiveness of Portland's UGB by analyzing the locational distribution of residential development in the region during the late 1980s. They found that single- and multi-family housing developments there (captured with the use of residential building permits, land divisions, and detailed density information) tended to be located within the region's growth boundaries, while considerable development continued at the edge or outside of the boundaries. In the following year, the authors investigated the case of the Medford metropolitan region in Oregon, using an expanded list of development indicators, covering both residential and commercial/industrial development profiles (Moore and Nelson, 1994). Their results, e.g., over 70% of newly created lots and nearly all new multiple-family housing and commercial/industrial construction occurred within the boundaries, again suggested that Oregon's UGB initiatives appeared to make a meaningful difference in shaping development patterns. Kline and Alig (1999) reported a similar finding about the effectiveness of Oregon's UGBs, using the USDA Forest Inventory and Analysis dataset that dated back to 1961. More specifically, their probit models yielded statistically significant estimates, indicating that "Oregon's land use planning program has concentrated development within urban growth boundaries since its implementation" (p.15), even though it was unclear whether the state was successful in preserving resource lands.

However, while the early case studies above suggested that policy would be effective in promoting more compact and contiguous development, this conclusion has not always been upheld by other studies. In fact, more recent evaluations, which have been carried out in a divergent fashion in terms of both research design and study areas, have reported mixed findings. Whereas a few recent studies have achieved results supporting the effectiveness of UGBs, at least partially (see, e.g., Nelson et al., 2004; Carlson and Dierwechter, 2007), Jun (2004) raised a question about the policy's effectiveness based on his comparison of Portland with other metropolitan areas with a population over one million in 1980 and statistical analysis of housing supply using census block group-level data for the Portland region. Similarly, by analyzing land development patterns in and around Knoxville, TN, with the use of two-stage probit and neural-network models, Cho et al. (2007) found that Knoxville's UGB adopted in 2001 did not succeed in curtailing sprawl in the region. Rather, they reported that "the sprawl toward west Knox County has been more intense during the post-UGB period than the pre-UGB period. Although the cause of more intense sprawl in the west outside of the city boundary during the post-UGB period is not clear, this pattern of development confirms the insignificant role of UGB" (p.715).

It is important to note that some recent studies have indicated the variation in policy outcomes more explicitly. Woo and Guldmann (2011), for example, showed a sizable magnitude of the variation in urban containment policy outcomes that they thought was attributable to the varying tightness in policy implementation. In his investigation of the Portland's UGB using a spatial market disequilibrium model, Kim (2013) demonstrated that the effectiveness of a city's UGB might be largely dependent on the attitudes of neighboring jurisdictions and thus could vary inevitably across regions/times. Furthermore, Dempsey and Plantinga (2013) detected a significant variation in the effectiveness of UGBs in containing development across cities, in their study using fine-scale data on cities in the state of Oregon. Kline et al. (2014) also provided evidence showing the possibility of varying results across counties within a single metropolitan area, due to the varying governance regimes. They stated that "[the] effects have varied across individual counties, likely owing, in part, to differences in counties' initial levels of development, distinctly different land use planning histories, and how restrictively their urban growth boundaries were drawn" (p.62).

In sum, previous research has been mixed about the effectiveness of UGBs and suggested that policy outcomes are likely to be context sensitive. This is true not only for cases in the US but also for those in other countries (see, e.g., Gennaio et al., 2009; Frenkel and Orenstein, 2012;

Wang et al., 2014). While UGBs are able to control sprawl and induce a more compact and contiguous form of development, the policy does not always work as expected or guarantee desired outcomes.

Policy Outcome Variation – Why Equivocal?

The variation in UGB outcomes reported in the literature cannot be fully explained by a single factor. Undoubtedly, the mixed results are in part due to variation in research (or evaluation) design. Policy evaluation does not always occur in a perfectly consistent fashion. In fact, evaluation studies substantially differ from one to another in terms of their modes of analysis, metrics, data sources, and other details (Guyadeen and Seasons, 2018). Among others, the evaluation outcomes largely depend on research design, particularly the baseline (or benchmark points) used to determine the extent to which UGBs result in a change in physical development patterns. The choice of metrics can also make a difference, as land cover change, building permits, density metrics, and other indicators do not necessarily tell the same story. For a similar reason, the evaluation outcomes can be influenced more or less by data sources. Kline (2000) illustrated this point by indicating "the problems associated with relying on data reported in the US Census of Population and the US Census of Agriculture to evaluate urban sprawl and farmland preservation" (p.349). He showed how the values of indicators could differ when computed with an alternative data source, namely, the National Resources Inventory dataset. Thompson and Prokopy (2009) also stressed the importance of data sources in analyzing land use patterns and informing relevant policies.

Even if the policy outcomes were evaluated through an identical procedure with the use of the same metrics and data, a large extent of the variation would still exist due to differences in detailed policy design and/or enforcement schemes. Although the logic of UGBs is quite straightforward, it is not implemented in the same way across regions or times. According to Nelson and Dawkins (2004), urban containment policies (including UGBs) can be classified into four distinct categories (weak-restrictive, strong-restrictive, weak-accommodating, and strong-accommodating) that differ from one another in the way the policies are implemented. In their investigation of the UGBs' impacts on density gradients, Woo and Guldmann (2011) considered the differences in the tightness of policy enforcement and found that "state-mandated 'strong' containment policies accommodate growth within the growth boundaries more effectively than locally adopted UGBs" (p.3530). Kline et al. (2014) also detected considerable variation among counties in their examination of the effectiveness of UGBs in the Portland, OR-Vancouver, WA region, where they analyzed land use data from the mid-1970s to the mid-2000s using a difference-in-differences model. According to the authors, the detected variation could be attributed to different governance regimes, specifically "a willful lack of adequate enforcement in some counties, resulting in improper development mostly in exclusive agricultural use zones … and differences in the criteria individual counties use to determine allowable development outside urban growth boundaries" (p.61).

Although the policy outcome variation could be attributed to the above two reasons (i.e., differences in research/evaluation settings and those in policy design/implementation), a more profound reason appears to exist behind the variation, that is, the so-called "context". Each city/region is unique in many aspects, even though this does not necessarily mean that no comparison or generalization is possible. Furthermore, given the evolving nature of cities/regions, a policy instrument would never lead to a temporally invariant outcome. In this sense, the policy outcome variation is inevitable, and understanding how it varies (and under what contexts it is more likely to function effectively) should be placed high on the priority list of land use research and policy deliberation.

It should be noted that this context-oriented reasoning is not completely separable from an earlier explanation, namely, the variability in policy design and/or implementation as a cause of the mixed outcomes. The varying contexts can shape the fundamentals of policy design or formulation processes differently and thereby result in different policy outcomes. To some extent, the variance can also emerge across contexts via subtle alterations in policy design or the strictness in policy enforcement.

However, the contextual differences generally refer to much more than the dissimilarities in policy design or implementation in explaining why the literature is so equivocal regarding the effectiveness of UGBs or other land use policy instruments. It covers a wide range of features that set the stage for putting a policy in motion. These include external forces that evolve over time and thus lead to temporal variability in policy outcomes, even if there has been no change in policy design or implementation schemes. The (policy) context also encompasses nuanced internal settings that cannot be easily captured by a single conventional variable, but nonetheless reshape the mechanisms by which a land use policy works in an intended or unexpected fashion.

While the context-oriented explanation for policy outcome variation is quite prevalent, what is meant by “context” is not always clearly articulated in the planning literature. Rather, it oftentimes remains a vague term to which the mixed findings are attributed. In some cases, it seems to cover all the profound differences between places (or time points) in which a certain policy is found to result in distinct outcomes, including historical backgrounds, cultural milieus, and political regimes. In other cases, it appears to refer to more narrowly defined forces or conditions, such as big vs. small cities, growing vs. declining phases, fragmented vs. consolidated governance settings, and so forth. In any case, it does not indicate a single factor but includes an array of elements that are somehow intertwined with each other and collectively form the setting for policymaking and implementation.

Understanding what constitutes the "context" is crucial, and more attention should be paid to what contextual factors matter and why. This line of research would enable us to gain more fruitful insights and advance our knowledge about land use dynamics. The following section will present an empirical analysis of various contextual factors that could help explain variation in land use policy outcomes, specifically the effects of UGBs on physical development patterns.

Analysis of Contextual Factors – Sample, Data, and Methodology

To better understand the mechanisms behind the varying nature of policy outcomes, this study examines how the effectiveness of UGBs varies and what contextual factors can account for the variation. More specifically, using a sample of US metropolitan areas, it analyzes the policy's impacts on two key outcome variables: 1) population density changes and 2) patch density changes that represent the degree of compactness and development contiguity in each region, respectively. In other words, the present analysis focuses on the extent to which UGBs contribute to achieving the policy's primary goal, namely, achieving a more compact and contiguous pattern of physical development.

The sample considered includes 85 single-county metropolitan statistical areas (MSAs) with a population between 100,000 and 500,000 in 2000. While the Anchorage, AK, MSA is excluded from the sample given its unique location, all other MSAs that meet the aforementioned population range and single-county conditions are included. It needs to be noted that this study does not consider multi-county MSAs due to the difficulties in identifying the presence of UGBs precisely for these regions, particularly for those in which some counties (or municipalities) have implemented UGBs, but others have not. However, as shown in Figure 1, the sample covers the entire nation reasonably well from the east to the west, including at least one MSA from 28 states.

<< Insert Figure 1 about here >>

For each of the 85 MSAs, the presence of UGBs is identified by utilizing multiple sources of information, including previous research (e.g., Anderson, 1999; Burby et al., 2001; Nelson and Dawkins, 2004), state-level resources (e.g., California Planners' Book of Lists), and official county/municipality websites. Specifically, this study focuses on whether each region had the policy in place in year 2001 (*UGB*=1) or not (*UGB*=0). Even though this dichotomic representation of UGBs (presence or absence of the policy in a certain year) is not ideal, it offers an opportunity to investigate how UGBs can modify physical development patterns over the subsequent years using data from a number of regions that are situated in varying contexts.

As briefly mentioned above, this study examines the effectiveness of UGBs and its variation with a focus on population density and patch density change rates for the subsequent 10 years, 2001-2011. Population density is one of the most widely used indicators to measure the compactness of urban development, particularly useful when a number of regions need to be investigated and compared, as in the present study. In the literature, patch density has been used as an inverse proxy for contiguity, because a more fragmented (or leapfrogging) pattern of physical development involves a higher level of patch density, i.e., a larger number of patches in a certain area (see, e.g., Weng, 2007; Kaza, 2013).

To construct the two-policy outcome variables, this study employs the National Land Cover Database (NLCD), which provides high-resolution (30 m×30 m scale) land cover information for the entire nation (see Homer et al., 2015 for more detailed information about the land cover dataset). For year 2001, the 2011 edition of the NLCD 2001 is used to ensure the compatibility. Population density levels are calculated by dividing each MSA's total population by the size of developed surface within the region derived from the NLCD layers. The NLCD information is also used to compute the values of patch density to measure the effectiveness of UGBs in inducing a more contiguous pattern of development. In calculating the patch density values, the original NLCD land cover classification scheme is aggregated, because the focus here is the degree of contiguity in development for urban purposes, as opposed to more or less fragmentation in detailed classes of green space.

Table 1 presents a comparison of two groups of single-county MSAs. Group 1 has 35 regions with UGBs, and Group 2 has 50 regions without such containment policies, in terms of population and patch density changes. As shown in the table (upper side), the UGB regions generally show a more rapid increase in population density and a slower pace of patch density increase, indicating that these areas have been more successful in realizing a more compact and contiguous form of development between 2001 and 2011 than their counterparts. However, when a similar comparison is made for two sub-periods of time (2001-2006 and 2006-2011; Table 1, middle side), it is found that the density change differences between the two groups are significant only in 2006-2011, showing the possibility of varying policy outcomes reported in the literature. Likewise, if the two groups are compared after sub-dividing the sample based on population size or population growth rates (Table 1, bottom side), it becomes clear that the gaps are more apparent in one setting (i.e., smaller and slowly growing regions), while the presence of UGBs does not seem to make that much difference in other circumstances.

<< Insert Table 1 about here >>

Admittedly, the detected gaps are not necessarily attributable to the presence of UGBs. Other factors could make a noticeable difference in population and patch density changes. A more plausible evaluation of the policy outcomes/effectiveness can be made through a multivariate analysis that controls for the influences of all other relevant forces. However, conventional, linear regression models have limited usefulness in understanding the mechanisms behind varying policy effects, because these models are designed to estimate the fixed marginal effect of the policy variable (and other covariates) rather than to address the possible nonlinearities and complex interactions between the variables. This rigidity can also lead to a misspecification bias.

As discussed above, the policy outcomes are never uniform. UGBs are more or less likely to be effective when certain conditions are met, whereas the policy would not bring the same benefits in other contexts. The impact of UGBs on population and patch density changes can be dampened or amplified by a variety of contextual factors (see solid blue lines in Figure 2). At the same time, the presence or absence of UGBs can also modify the net contributions of other factors to more compact or contiguous development (see dotted lines in Figure 2). For instance, political fragmentation can induce a more sprawling pattern of development but not in the same fashion, depending on the existence of UGBs.

<< Insert Figure 2 about here >>

Therefore, this study employs an alternative multivariate analysis approach, namely a kernel-based regularized least squares (KRLS) method (Hainmueller and Hazlett, 2013). The KRLS estimation provides a useful way of capturing (potentially) complex interactions between various determinants in explaining the detected variation in the dependent variable, with consideration of the tradeoff between model fit and complexity. The main advantage of this method is the flexibility it provides. Specifically, rather than yielding a fixed estimate of each determinant, it enables one to obtain "pointwise estimates of partial derivatives that characterize the marginal effect of each independent variable at each data point in the covariate space … [and thus] examine the distribution of these pointwise estimates to learn about the heterogeneity in marginal effects or average them to obtain an average partial derivative similar to a beta coefficient from linear regression" (p.144, Hainmueller and Hazlett, 2013).[1]

The pointwise estimates present a valuable opportunity to understand the mechanisms behind the policy outcome variation in two senses. First, they can reveal how the effect of a policy (UGB) on the dependent variable (population or patch density changes) varies across observations in the sample (i.e., regions that were situated in distinct contexts). Second, it is also possible to see how the impacts of other determinants on the outcome variable differ in the regions with and without the policy. The presence of UGBs can not only have a direct effect but also reshape the way other factors affect physical development patterns by functioning as a moderator. Once a multivariate analysis is conducted through KRLS, as in this study, the pointwise estimates yielded can be used to check various possibilities, such as whether an increase in housing prices can induce a higher density in the regions with/without UGBs, and vice versa. In other words, a KRLS-based analysis can provide useful insights by showing how the UGB estimates vary and at the same time by revealing how the presence of UGBs can alter the relationship between the policy outcome and other determinants.

It is important to note that KRLS works nicely even with a small sample size (Ferwerda et al., 2017). Given the small sample size (n=85), however, a group of explanatory variables are carefully selected and constructed based on the studies reviewed (see Section *Previous Research – Mixed Findings*) to control for their effects on physical development patterns and examine how they interact with UGB and create varying outcomes. Table 2 provides a summary of these variables, including population size, population growth rates, housing price (normalized by the median household income in the region), and several additional variables that can represent other contextual factors and thus account for some extent of the variation in policy outcomes. In measuring the variables, as explained in Table 2, various sources of county-level data for 1990 (or the closest data year) are used to avoid potential simultaneity problems.

<< Insert Table 2 about here >>

Three of these variables (*Creative.Pct*, *HHI* and *Within.JTW.Pct*) may require a more detailed explanation. *Creative.Pct* indicates each (single-county) MSA's proportion of employment in creative class occupations. Although it is not completely clear in the literature what should constitute the so-called creative class (Florida, 2002), this metric (made by the USDA Economic Research Service) provides a great opportunity to examine how each region's physical development patterns can be shaped by its socio-economic composition. It has been suggested that the creative class (or creative industries) would prefer certain attributes of urban form, such as high-density, transit-friendly, and mixed-use developments, while housing costs and other classic location factors do matter (see, e.g., Mansury et al., 2012; Lawton et al., 2013, Spencer, 2015). This group of population (or businesses) can also influence the way in which future development is regulated and thus generate variation in policy outcomes (Natekal, 2018). For instance, it would be possible for a region with a high *Creative.Pct* to promote compact development even without adopting a formal containment policy. If this is the case, the marginal impact of UGBs on density increases will be smaller with a higher percentage of the creative class.

HHI, which refers to the Hirschman-Herfindahl Index, is employed to measure the structure of governance in each region. The metric is designed to yield a value between $1/m$ (where m is the total number of government units in the MSA) and 1 (the maximum value). A lower value generally indicates a higher degree of decentralization (or political fragmentation), with a more evenly distributed pattern of government expenditures among municipalities. A higher value of *HHI* suggests that the spending is dominated by a single jurisdiction in the region, i.e., political power concentration (see, e.g., Grassmueck and Shields, 2010; Hendrick et al., 2011; Kim et al., 2015). Recent studies have suggested that political fragmentation in local/regional governance can lead to a more sprawling pattern of development (see, e.g., Razin and Rosentraub, 2000; Carruthers and Ulfarsson, 2002; Byun and Esparza, 2005; Kim et al., 2015). As a contextual factor, the governance structure can also significantly modify the effectiveness of UGBs in promoting more compact or contiguous development.

In addition to the internal (governance) structure of each region, this study attempts to take into account external conditions, another aspect of the context considered important in a range of planning practices. *Within.JTW.Pct* is constructed for this purpose. It indicates what percentage of the total commuters in each single-county MSA lived and worked in the region as shown below, and thus represents the degree to which each MSA is associated with surrounding areas in terms of commuting.

$$Within.JTW.Pct = \frac{2 \times (\#\ of\ commuters\ living\ and\ working\ in\ the\ MSA)}{(Total\ commuting\ inflows) + (Total\ commuting\ outflows)}$$

The maximum possible value is 1, indicating that all of the commuters were living and working in the MSA (i.e., zero commuting across the MSA boundaries). A lower value represents a higher degree of reliance or interaction with surrounding regions. In the sample, the Auburn–Opelika, AL, MSA showed the lowest value, 0.790, as it had a substantial number of commuters to/from the nearby Columbus, GA-AL MSA. In contrast, Laredo, TX, Grand Junction, CO, Eugene--Springfield, OR, and some other MSAs exhibited a much higher value for this metric, because they were largely self-sustaining in terms of commuting flows in 1990.

Results – Determinants of the Policy Outcome Variation

Under what circumstances can UGBs induce a more compact and/or contiguous pattern of development? What are the factors that can account for the variation in policy outcomes? To answer these questions, a multivariate analysis was conducted as explained in the previous section with the data for 85 single-county MSAs in the US. This section presents the analysis results for each of the two outcome variables used: 1) population density change rates (logged); and 2) patch density change rates (logged) between 2001 and 2011.

Population Density Change Model – UGB Effects and Their Variation

First, the results for population density change are summarized in Table 3. The OLS estimates show that the presence of UGBs is positively associated with population density change rates, but the effect is statistically insignificant. This result suggests that the sizable gap between regions with and without UGBs (shown in Table 1) is largely attributable to other determinants. *Pop.Growth* (population growth rates between 1990 and 2000) turns out to be a crucial driver of population density increase. *Pop.Density.01* (population density level in the initial year) and *Housing.Price* (each region's housing value normalized by its median household income in 1990) are also found to play an important role in determining the level of compactness in urban development.

<< Insert Table 3 about here >>

The KRLS estimation, which provides pointwise estimates as opposed to a single fixed value for each coefficient, suggests that the impact of UGBs on population density changes varies substantially. While the average value of the estimates (+0.009) does not significantly differ from the value obtained from OLS (+0.010), the KRLS analysis outcomes show a wide range of estimates with +0.003 at the first quantile (25%) that point to +0.019 at the 75% percentile level. An important question here is the circumstances under which these estimates tend to be larger. This can be addressed by looking into the detailed patterns of the pointwise estimates. Figures 3 and 4 demonstrate the patterns by plotting the UGB estimates along with other factors considered. The UGB effects are found to be larger in the areas when *Pop.Density.01* is low, *Pop.Size* is low, *Pop.Growth* is low, *Per.Capita.Income* is high, *Creative.Pct* is low, and *HHI* is low. The relationship is particularly apparent in the areas with low *Pop.Density.01* levels, suggesting that UGBs would enable low-density regions to achieve a large net density increase, while it may not have the same effect on further density increases in high-density areas.

<< Insert Figures 3 and 4 about here >>

Population Density Change Model – Moderating Effects

Another aspect to explore is how the estimates on other determinants differ in the regions with and without UGBs. As noted in the previous section, UGBs can moderate the impacts of other factors on physical development patterns. The pointwise estimates on each tested variable from the KRLS estimation are juxtaposed in Table 4 to check this possibility. As shown in the table, the presence of UGBs appears to alter substantially the way in which *Creative.Pct* and *HHI* influence population density changes. The magnitude of the effect of *Creative.Pct* is found to be lower in areas with UGBs, indicating that the contribution of creative class occupations to more compact development tends to be larger, when UGBs do not exist. This finding may suggest that density increase is not an additive result of independent factors but rather an outcome that can be achieved either by implementing a formalized policy such as UGBs or having a certain characteristic of residents (e.g., a large proportion of the population who are in favor of dense built environments). For this reason, the net contribution of certain population groups to density increase can be larger without UGBs, as detected here. Regions that lack such a favorable (demographic/economic) composition would get more help from UGBs in moving toward a more compact form of physical development.

<< Insert Table 4 about here >>

A similar type of reasoning can be applied to interpreting the pattern of *HHI*'s estimates that turn out to be larger in regions with UGBs. The positive sign of *HHI*'s coefficient indicates that population density can rise more substantially in a less fragmented governance setting (consistent with the findings from studies on the relationship between political fragmentation and sprawl). This pattern turns out to be more obvious in the areas where UGBs are present, which makes sense because the benefit of consolidation (or the negative impact of fragmentation on density) can make a considerable difference when an action (UGBs) is implemented. Without a policy action or interest in a certain goal, the governance structure would not matter much on that front.

There are several other notable findings from the KRLS analysis. First, compared to OLS, the KRLS estimation yields a much larger R-squared, indicating that this new estimation approach explains a greater extent of the variation in the dependent variable. This R-squared improvement may also imply that density changes cannot be easily characterized as a simple additive sum of the fixed effects of independent variables. In other words, the density change dynamics (or urban development patterns, more broadly) are likely an outcome of various forces and relevant policy interventions that interact with each other in a complex, nonlinear fashion. It should also be noted that the impact of some variables can be more apparent when analyzed using KRLS techniques. For instance, *Housing.Price* exhibited a more significant, positive impact on population density changes (+0.048 under KRLS, compared to +0.033 under OLS), suggesting that a higher housing price can lead to more dense built environments, as predicted by urban economic theories.

Patch Density Change Model – UGB Effects and Their Variation

Table 5 presents the results for the second outcome variable, namely, patch density change rates between 2001 and 2011 (logged), which is an inverse proxy of contiguity. Again, the presence of UGBs did not show a statistically significant impact under OLS, while the sign of the UGB coefficient was negative (indicating a relative contiguity increase in the regions with UGBs compared to those without UGBs), as anticipated. Instead, *Housing.Price* is found to matter most (the more expensive, the more contiguous). In addition, *Patch.Density.01* (patch density level in the initial year) also exhibits a statistically significant negative coefficient, indicating a tendency of convergence in the dynamics of patch density change.

<< Insert Table 5 about here >>

Similar to the findings for population density change rates, the KRLS estimation results show the varying nature of the UGB effects on development contiguity. More specifically, it is detected that the policy's contribution to inducing a higher level of contiguity tends to be more substantial in regions with a lower initial level of patch density and a smaller population size (Figure 5). This result is consistent with what was found from the population density change model earlier in the sense that the policy outcomes are likely to be dependent on the implementing region's size and initial development patterns.

Moreover, in the case of patch density change, the impacts of UGBs are stronger when *Within.JTW.Pct* is high (Figure 6). This result suggests that UGBs are more likely to be effective in inducing a contiguous pattern of development in self-sustaining regions where the possibility of development spillover to adjacent areas is low. On the contrary, in regions having a greater dependence on nearby areas, UGBs would not be equally successful unless the policy was implemented in coordination with neighboring cities or counties (Kim, 2013). This finding deserves attention, as it highlights the importance of external (or geographical) settings in determining the effectiveness of land use policies.

<< Insert Figures 5 and 6 about here >>

Patch Density Change Model – Moderating Effects

As explained above, UGBs can act as a moderating variable that can influence the way in which other factors shape development patterns. In the case of patch density change, the presence of UGBs is found to alter the impacts of some of the tested variables significantly, as shown in Table 6. Among others, the marginal impact of *Within.JTW.Pct* appears to differ most substantially between UGB and non-UGB groups. *Within.JTW.Pct* shows a negative association with patch density change rates only in the regions with UGBs, suggesting that self-sustaining regions may have advantages in achieving a more contiguous pattern of development only when the policy is in place.

It is important to note that the net contributions of other variables tend to be larger in non-UGB settings. For instance, the converging force (detected by *Patch.Density.01*) appears to be stronger in regions without UGBs. In addition, an increase in *Pop.Size* turns out to have a larger impact on development contiguity in non-UGB areas, while the presence/absence of UGBs does not seem to significantly modify the relationship between *Pop.Growth* and patch density change rates. These results indicate that other factors may play a more significant role in determining the level of development contiguity in the absence of policy interventions.

<< Insert Table 6 about here >>

Summary and Discussion

In recent years, land use planners have been confronted with enormous challenges and problems. There have long been concerns about unlimited expansion of urban territory, failures to protect environmentally sensitive areas, and growing ecological footprints, requiring timely responses to better use and preserve valuable land resources. At the same time, rising inequalities and volatile economies have made the problem more complex. Today, the mission of land use planning is not simply to protect air quality or avoid conflicts among different land uses but identify ways to navigate the path toward a more economically prosperous, socially inclusive, and environmentally sustainable future by taking appropriate actions at various levels.

In many places, these challenges have increasingly urged us to discern the qualities of various policy instruments and implement *good* policies in an effective manner. However, what are *good* policies? Urban growth boundaries? Impact fees? Form-based codes, as opposed to traditional zoning ordinances? Is one combination of these tools better than another?

As discussed throughout this article, it is hardly worthwhile to seek a panacea. A policy that works in some places may not necessarily induce the same outcome in other settings. Understanding the contexts in which a specific policy is likely to perform well is extremely crucial. In this light, the present study attempts to advance our understanding of the context-sensitive nature of land use policy outcomes and uncover some meaningful patterns of the varying policy (UGB) effects in association with some contextual factors.

According to the analysis results, the effectiveness of UGBs in attaining the policy's primary goals is highly associated with multiple contextual factors. Among others, the presence of UGBs seems to contribute more to compact and contiguous development in single-county MSAs with a relatively smaller population size. Population density increase can also be promoted by UGBs more effectively when the density level was low in the initial year of analysis. In terms of the contiguity of physical development, UGBs are found to be more beneficial in self-sustaining regions in which most people lived and worked rather than commuting across MSA boundaries. Furthermore, the policy seems to play an important role in mitigating or amplifying the impacts of other determinants on physical development patterns.

Admittedly, this study is not without limitations. It focuses on net population and patch density changes between 2001 and 2011 with no exploration of the historical background of the policy implementation in each region, associated temporal variability, or the policy's effectiveness in achieving other goals. The binary UGB variable used is also limited in the sense that the policy can have different effects depending on whether it was mandatory or not and how long (and how well) it has been implemented. Due to the sample size, consideration is mainly given to some selected contextual factors, leaving other dimensions for future work.

It is also questionable whether the findings derived from the sample used–85 single-county metropolitan areas in the US–can be applied to other cities or regions, particularly large (multi-county) metropolitan areas where the planning environment tends to be more complex or even fragmented. Furthermore, one could argue that the method (KRLS) used in this study would not necessarily be the best approach for revealing the underlying factors that create significant variation in policy outcomes. A meta-analysis (or a careful review/comparison of case studies) could also be performed for this purpose, once we have a large number of comparable evaluation studies have been conducted.

Nonetheless, this study provides a way to sharpen our understanding of the nature of varying policy outcomes and the importance of various contextual factors. Although the variables tested in this article may not include all possibly relevant contextual factors, the analysis presented here can enable us to gain new insights into the complex mechanisms through which land use policies, specifically UGBs, contribute (or fail to contribute) to inducing more compact and contiguous development in various settings. The study also shows the need for further research in this line toward a more complete understanding of context-specific land use policy effects. Land use planners and researchers are encouraged to investigate and report how their land use policies have worked with careful attention to potential influences of both internal and external settings in which the policies have been formulated and implemented.

Notes

[1] The logic behind this estimation approach draws from the literature on machine learning, in which a number of (kernel-based) new algorithms have been developed for various analytical purposes (see, e.g., Rifkin et al., 2003; Lv and Fan, 2009). For the KRLS application to planning-related issues, see, e.g., Weichenthal et al. (2016) and Hipp et al. (2017).

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